Cross-ministerial Strategic Innovation Promotion Program

「Cross-ministerial Strategic Innovation Promotion Program (SIP)/ Automated Driving for Universal Services/ Improvement of Data Accuracy of Traffic Regulation Information」

FY 2020 Report

Japan Road Traffic Information Center
ZENRIN CO., LTD

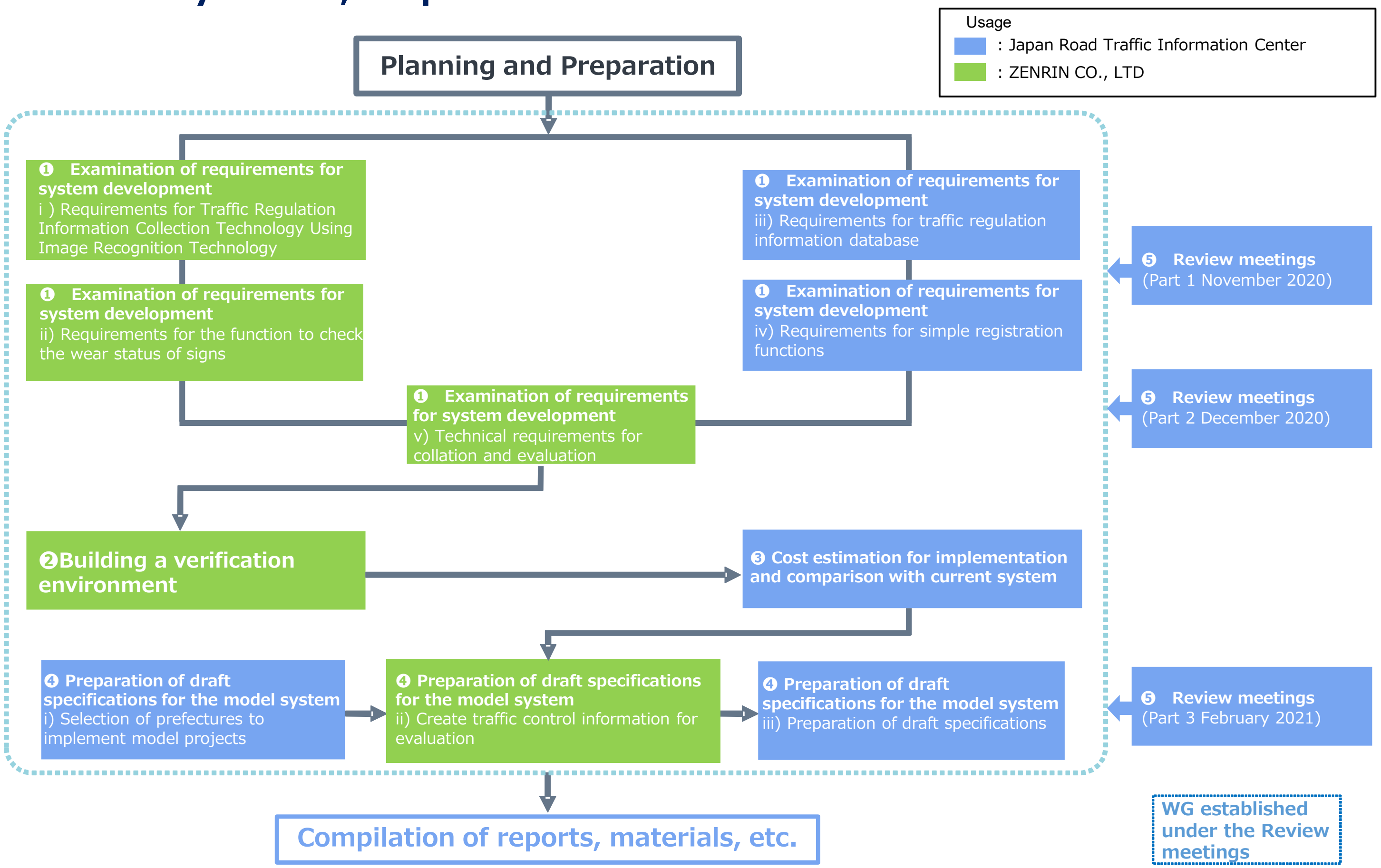
March, 2021

1. Objective of Reserch

◆Objective

This research aims to examine the technical requirements to improve the accuracy of traffic regulation information and stock management efficiency and to develop the system. This system photographs road sign/road marking information by a smartphone or an in-vehicle camera and automatically collected with uniform data accuracy using image recognition technology. Image recognition technology recognizes regulation types, location information, and the deterioration status of facilities. Also, the road sign/road marking information is collated with Police-managed traffic regulation information and registered with a simple registration function.

◆Research Survey Items, Implementation Flow



2. Examination of requirements for system development

i) Technical requirements for collecting traffic regulation information using image recognition technology

①Requirements for the data to be collected

Questionnaires and interviews were conducted with three automobile manufacturers regarding the location accuracy of traffic regulation information required by automated vehicles (Table 1). Since automated driving on general roads will be developed in the future, the responses were mainly based on the assumption that the vehicles will be driven on expressways, and the required positional accuracy also differs depending on the purpose of use of the information.

②Image date collection methods

The evaluation was conducted after comparing and organizing the characteristics of three items: image data collection equipment, collection subject, and communication method.

③Image recognition technology

In addition to noise, blur, and insufficient resolution, image data from drive recorders are subject to issues such as weather, nighttime, shade from street trees, deterioration, deformation, shooting angles, and pranks that resemble graffiti (Fig. 1 top). As a measure to improve recognition accuracy, it is effective to have the system generate and learn images that reproduce various issues from a single image (Fig. 1 bottom).

Table 1. Outline of hearings with automobile manufacturers

Question	Automobile manufacturers		
	Company A	Company B	Company C
Target road	Freeway	Road	Freeway and Road
Traffic regulation information types required for automated vehicle control and ADAS	(Required for high-speed driving) 26 types required for control and ADAS	92 types are required for control and ADAS, and others are highly effective when expanding functions.	101 types
Types of information lacking in the traffic regulation information	None	Mostly covered, but I'd like to see a maximum speed of 120km/h added.	None
Accuracy of traffic regulation information (relative accuracy, absolute accuracy, etc.)	In the case of up to the judgment and operation dimensions of the control system, lane level in the lateral direction and ±100m in the front-back direction including driver alerting	Relative and absolute accuracy is required with an accuracy (within a few tens of cm) that allows safe control of the vehicle.	In terms of surface regulation, for example, a system that cannot be mistaken for an adjacent intersection is desirable. For line regulations, for example, it is desirable to have a system that can distinguish between adjacent lanes.
Update frequency of traffic regulation information	Hope to have a high degree of confidence in the accuracy of the results, so that I can see how well they match reality.	Wish to receive before the changes in traffic regulations take effect.	If there is a change in the location of the road, such as a change in road structure or redrawing of white lines, etc.

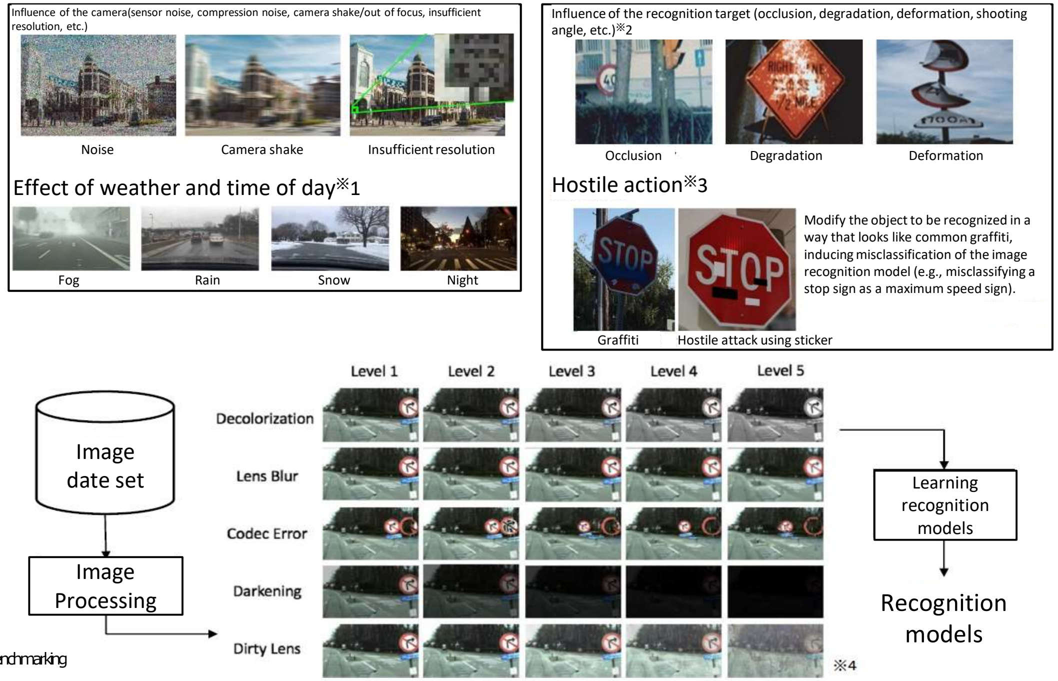


Fig.1. Top : Challenges in Image Recognition Technology
Bottom : Measures to improve recognition accuracy

※1 : Claudio Michaelis, Benjamin Mitzkus, Robert Geirhos, Evgenia Rusak, Oliver Bringmann, Alexander S. Ecker, Matthias Bethge, and Wieland Brendel, "Benchmarking Robustness in Object Detection: Autonomous Driving when Winter is Coming," arXiv, 2019.
※2 : Shadi Saleh, Sinan A. Khwandah, Ans Mumtaz, Ariane Heller, and Wolfram Hardt, "Traffic Signs Recognition and Distance Estimation using a Monocular Camera," APSSE, 2019.
※3 : Kevin Eykholt, Ivan Evtimov, Earlence Fernandes, Bo Li, Amir Rahmati, Chaowei Xiao, Atul Prakash, Tadayoshi Kohno, and Dawn Song, "Robust Physical-World Attacks on Deep Learning Models," CVPR, 2018.
※4 : Dogancan Temel, Gukyeong Kwon, Mohit Prabhushankar, and Ghassan AlRegib, "CURE-TSR: Challenging Unreal and Real Environments for Traffic Sign Recognition," NeurIPS Machine Learning for Intelligent Transportation Systems Workshop, 2017.

2. Examination of requirements for system development

ii) Requirements for the function to check the wear status of the markings

We studied the function of automating the classification of the wear rate of crosswalks according to the National Police Agency's notice through image classification using machine learning. For machine learning, labeling (annotation) for supervised learning is necessary, but in the case of ranks such as wear rate, which are influenced by individual subjectivity, there is a problem of labeling with variation. In this case, we confirmed that labels with less variation can be obtained by conducting annotation by multiple people. However, even with multiple annotators, there is a possibility that unreliable labels may be mixed in. To solve this problem, after labeling the images for training, labels with large variability are considered as low quality labels and are deleted. We confirmed that high-precision image classification is possible by learning with SSL (Semi-Supervised Learning) on mixed data sets with and without labels (Fig. 2).

iii) Requirements for traffic control information database

Based on the results of a questionnaire/hearing survey to automobile manufacturers and a questionnaire survey to prefectural police, the standard format (103 types) was reflected in the database (DB) of the model system as basic information. In addition, the prefectural police require a great deal of labor to match the content of signs and markings with traffic control information. In order to support this work, we considered taking photos of various information including the location of signs and markings with a smartphone, etc., and importing them into the DB. The results of collating (tentatively linking) the information of signs and markings with the standard format (103 types) imported into the model system are stored and managed in a temporary file in the DB of the model system, and the overall structure of the DB was considered (Fig. 3).

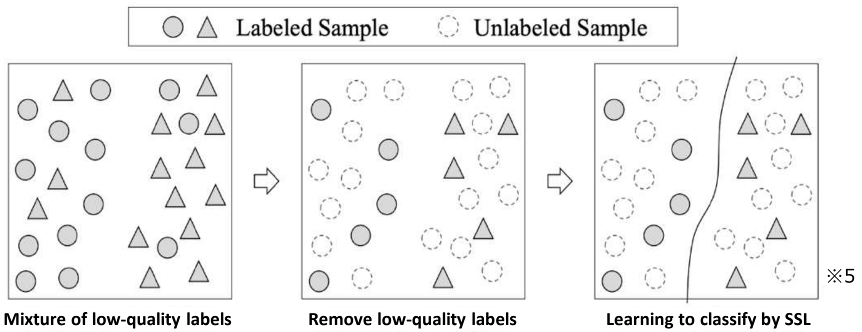


Fig.2. Image of learning with SSL

※5 Hwanjun Song, Minseok Kim, Dongmin Park and Jae-Gil Lee, "Learning from Noisy Labels with Deep Neural Networks: A Survey,"arXiv, 2020.

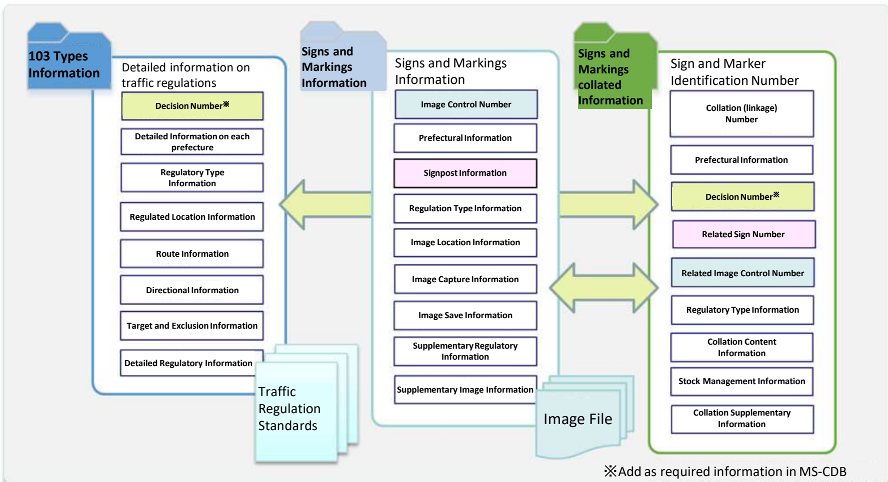


Fig.3. Overall structure of DB

2. Examination of requirements for system development

ⅳ) Requirements for simple registration functions

①Issues of registration services in prefectural police

We conducted a questionnaire survey of 47 prefectural police forces regarding the management and operation methods of traffic regulation information and sign/marking information, the status of linking traffic regulation information with sign/marking information, and current issues (Fig. 4). About 90% of the traffic regulation information is managed by "systematization" or "systematization and ledger (paper)," confirming that most of the information is managed in electronic data by the system. On the other hand, location information for traffic regulation information was not registered in about 60% of the cases. In addition, we conducted interviews with the Chiba Prefectural Police and Kanagawa Prefectural Police regarding the actual status of their existing systems and operational issues.

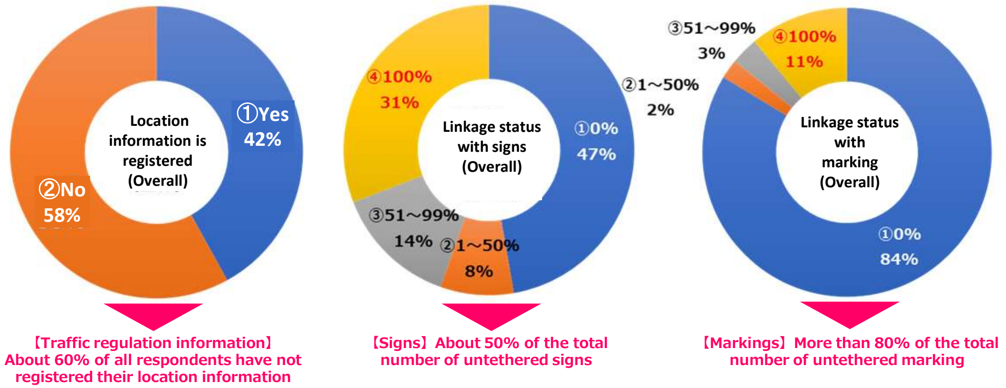


Fig.4. Results of a survey of 47 prefectures (excerpt)

Table 2. Issues in the current registration process

Registration of traffic regulation information	Registration of information on signs and markings
• It takes a lot of effort to input and link the information into the system. • It takes a lot of effort to identify the addresses of traffic regulation information from the Showa era. • The location of the regulation is unclear when the object that served as the address disappears. • Since traffic regulation information is managed using text-only data without location information, it takes a lot of effort to identify traffic regulation information when there is an inquiry about a section.	• The registration process is huge and time-consuming. • There is a shortage of staff for registration. • It is difficult to link them. • Signs and markings set up by road administrators are not understood. • Input errors occur. • Deterioration and wear status cannot be grasped. • There are inconsistencies and inconsistencies in the data. • Since the data is not managed, it is difficult to receive inquiries about the location.

② Simple registration function

In order to improve the efficiency and labor saving of the work for improving the accuracy of traffic regulation information data, it was decided that it is necessary to implement a system processing that can "predict the location of signs and markings, referring to the "Traffic Regulation Standards" issued by the National Police Agency, and select and confirm the candidate signs and markings from the information obtained from images, etc., for the work of linking traffic regulation information to signs and markings, which requires a lot of labor. In this paper, we summarized the necessity of realizing a system process that focuses on "predicting the location of signs and markings, and selecting and confirming the candidates to be linked from the information on signs and markings obtained from images, etc. As functions for this purpose, we examined the collation method (collation processing method) and the display/output method of the collation result (collation result).

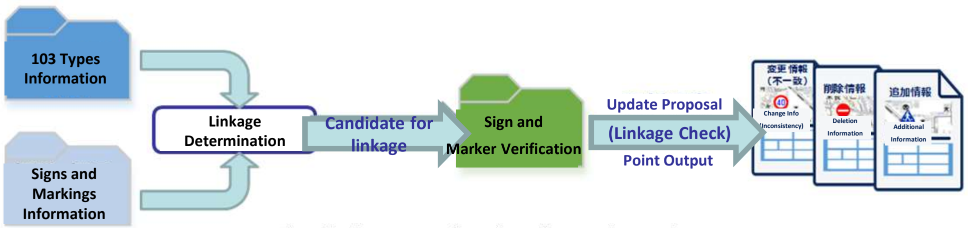


Fig.5. Image of a simple registration

2. Examination of requirements for system development

v) Technical requirements for verification and evaluation

①Consideration of collation method and collation scheme

We examined collation methods for information held by the prefectural police, information held by a private company (Zenrin), and information collected in the field (Table 3) for the three jurisdictions in Naka Ward, Yokohama City, Kanagawa Prefecture.

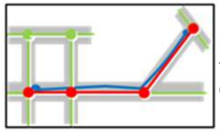
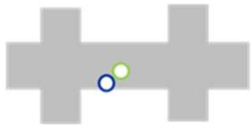
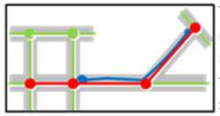
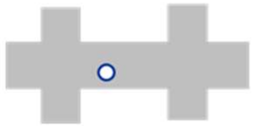
② Technical elements of collation evaluation

Based on the results of the collation method study, the technical elements of the collation evaluation in point regulation and line regulation were examined. In the collation of point regulations, the points are judged to match or disagree according to the distance between them, and if they match, the contents of the auxiliary sign information, etc., are compared to determine the match or disagreement. In the case of line regulation matching, A data is matched to the road shape of the private operator, and then matched to B data that has the same road shape, and the shape is judged to match or not match. In both types of matching, the results were manually checked after the machine processing judgment.

Table 3. Target Data

Type	Contents
A Data	Traffic regulation information (103 types) converted to standard format from traffic regulation information (decision-making information) held by prefectural police.
B Data	Traffic regulation information interpreted from signs and markings with location information provided to car navigation systems, etc. owned by private companies (Zenrin).
C Data	Information on signs and markings collected from image data from smartphones and drive recorders using image recognition technology.
A' Data	Data of the sign and mark management system held by prefectural police for the maintenance and management of signs and markings.
B' Data	Data on the contents of signs and markings to which location information is added that are owned by a private business operator (Zenrin).

Table 4. Examination of technical elements of collation evaluation (excerpt)

	Line Regulation	Point Regulation
Target Regulation Type	001. Pedestrian street 003. Roads for bicycles and pedestrians 004. Road closure 005. Closed to vehicles 011. One-way street (IN002) 032. Maximum speed 50km/h 033. Maximum speed 50km/h 034. Maximum speed 50km/h Legend: Standard Format Data; Private Company Data(Road shape); Private Company Data(Restricted area)	001. Pedestrian street 003. Roads for bicycles and pedestrians Legend: Standard Format data; Private company data
Consistent	 Regulatory sections of standard format data and private sector data match	 Regulatory sections of standard format data and private sector data match
Partially Consistent	 There are differences in the regulated sections of some roads between the standard format data and the private sector data.	
Inconsistent	 Standard format data only or Private sector data only	 Standard format data only or Private sector data only

3. Building a verification environment

Based on the results of the study of the technical requirements for collation and evaluation, a verification environment was constructed and three patterns of evaluation were conducted.

Collation and evaluation patterns❶

【 Results of survey of restricted sections and points 】

- ✓ As a result of cross-checking the A data with the B data, as shown in the table below, there were "1,123 matches," "250 partial matches," and "196 standard formats only.
- ✓ Furthermore, as a result of checking the field signs for "partial match" and "standard format only", we found 18 and 35 inconsistencies, accordingly.

Results	No. of events	Main cause		
		Regulatory information and sign status	No. of events	Notes
Consistent	1123	－	－	
Partially consistent ☆	250	No integration	18	Overlapping sections of the same regulation
		Integration	13	Due to variable sign status at the time of survey
		Unknown	219	
Standard format only☆	196	No integration	35	
		Integration	48	Signs on sidewalks
		Unknown	113	
Standard format No coordinates	357			No coordinate set in the coordinate field
Less than standard format	2042			Data in non-standard formats

【 Results of regulatory content survey 】

- ✓ As a result of confirming the regulatory contents of the "1,123 cases of agreement" among the above matching results, we found "1,034 cases of agreement" and "89 cases of disagreement.
- ✓ Furthermore, as a result of checking the local signs for the "discrepancies," 33 discrepancies with the standard format data were confirmed.

Results	No. of events	Main cause		
		Regulatory information and sign status	No. of events	Notes
Consistent	1034	－		
Non-Consistent	89	No integration	33	How to enter data (one- and two-sided codes)
		Integration	56	
		Unknown	0	

Collation and evaluation patterns❷

【 Collation results of sign and mark information 】

- ✓ As a result of cross-checking the 'A' data with the 'B' data, we found that there were 5,377 cases that matched, 1,794 cases that were police only, and 935 cases that were private businesses only.
- ✓ Furthermore, when we checked the local signs for "police only" and "private sector only," we found 8 and 17 inconsistencies, respectively.

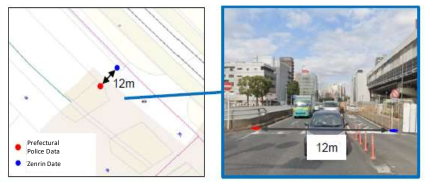
Results	No. of events	Main cause		
		Sign data and status of local signs	No. of events	Notes
Consistent	5377			
Police Only	1794	No integration	※1	Different car models in signs
		Integration		
		Unknown		Sighting distance is 10m or more
Private Companies Only	935	No integration	※2	
		Integration		
		Unknown		Sighting distance is 10m or more

※1 (No integration/Integration/Unknown/Sighting distance:8／8／51／18[cases])
※2 (No integration/Integration/Unknown/Sighting distance:17／25／39／13[cases])

【 Example of increased collision distance 】

- ✓ Since the probability of inconsistency or uncertainty increases when matching at the same point (latitude and longitude), the search distance was set to 10 m, starting from the latitude and longitude point of the sign post in the 'A' data to be matched.
- ✓ The reason for the 10-meter search distance was determined by taking into account the fact that more than 95% of the distances between the matched signs were less than 5 meters, as well as the input error during the mapping process and the error in the base map.
- ✓ On the other hand, as the matching distance is increased, there are more signs that seem to "match", but it is necessary to verify whether they are objects that should be matched or not.

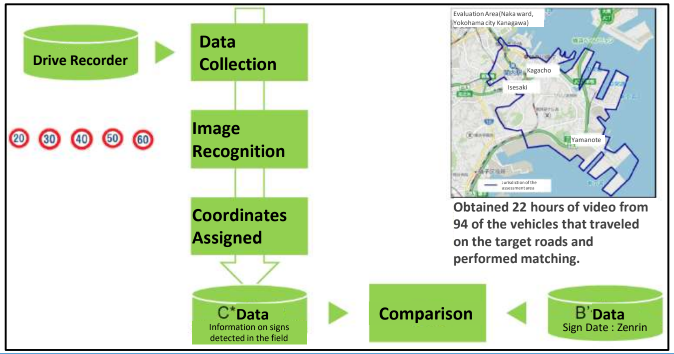
Example of a match that occurs when the collision distance is increased
(Distance is 10m, the distance between the data below is 12m)



3. Building a verification environment

Collation and evaluation pattern ❸

- The matching of 'B' data and 'C' data was limited to the maximum speed among the highway signs in the evaluation area.
- The following flow was conducted* by obtaining 22 hours of drive recorder video from 94 vehicles that drove on the target road.



【Factors to be considered in pattern ❸】

Scene	Summary of issues to be considered
During data collection	• In addition to photographs, position and orientation data are also required. • Recording cycle of photographs and position and orientation data. • How the object is photographed.
During image recognition	• Data used for learning and image recognition. • Continuous learning. Tracking of identical geographic objects.
When coordinates are given	• Obtain the coordinates of the target object, not the shooting position. • Position and orientation data is required for all photos taken.
During data comparison	• Distance to be considered corresponding.

*As the service is still under development and has not yet reached the specified performance level, this report is based on the findings from the service development and matching results, not the matching results themselves.

4. Cost estimation for implementation and comparison with the current system

In order to understand the effect of introducing the new system, we estimated the cost of introducing the new system, etc., based on three different model configurations, and confirmed that the cloud form in Pattern 2 is the most effective.

Table 5. Configuration pattern for cost estimation

Model configuration		Pattern 1	Pattern 2	Pattern 3
Software	Basic functions (DB management, collation, I/O, etc.)	Built on a server in the main part of the model system	Built on a server in the main part of the model system	Built on a server in the main part of the model system
Software	Image analysis function (location information extraction, etc.)	Embedded as a function in the server of the main part of the model system	Use the functions of an external server (solidarity)	Use the functions of an external server (solidarity)
Software	Signs and markings inspection function (App)	Distribute packaged software to prefectural police.	Distribute packaged software to prefectural police.	Introduced the function (App) in prefectural police.
Hardware		For the location of the main server of the model system, see I. On-premise/data center interest, II. Cloud (private) configuration.		

5. Preparation of draft specifications for the model system

i) Selection of prefectures to implement model projects

Kanagawa Prefecture was selected as the prefecture to implement the model project because it satisfies the number of data required for the functional verification of the model system in the next fiscal year, and decision-making information before standard format data conversion can be obtained.

ii) Create traffic control information for evaluation

Traffic regulation information for evaluation (CSV format) was created as data for the initial functional check of the model system to be built in the next fiscal year and for verification when all functions are used.

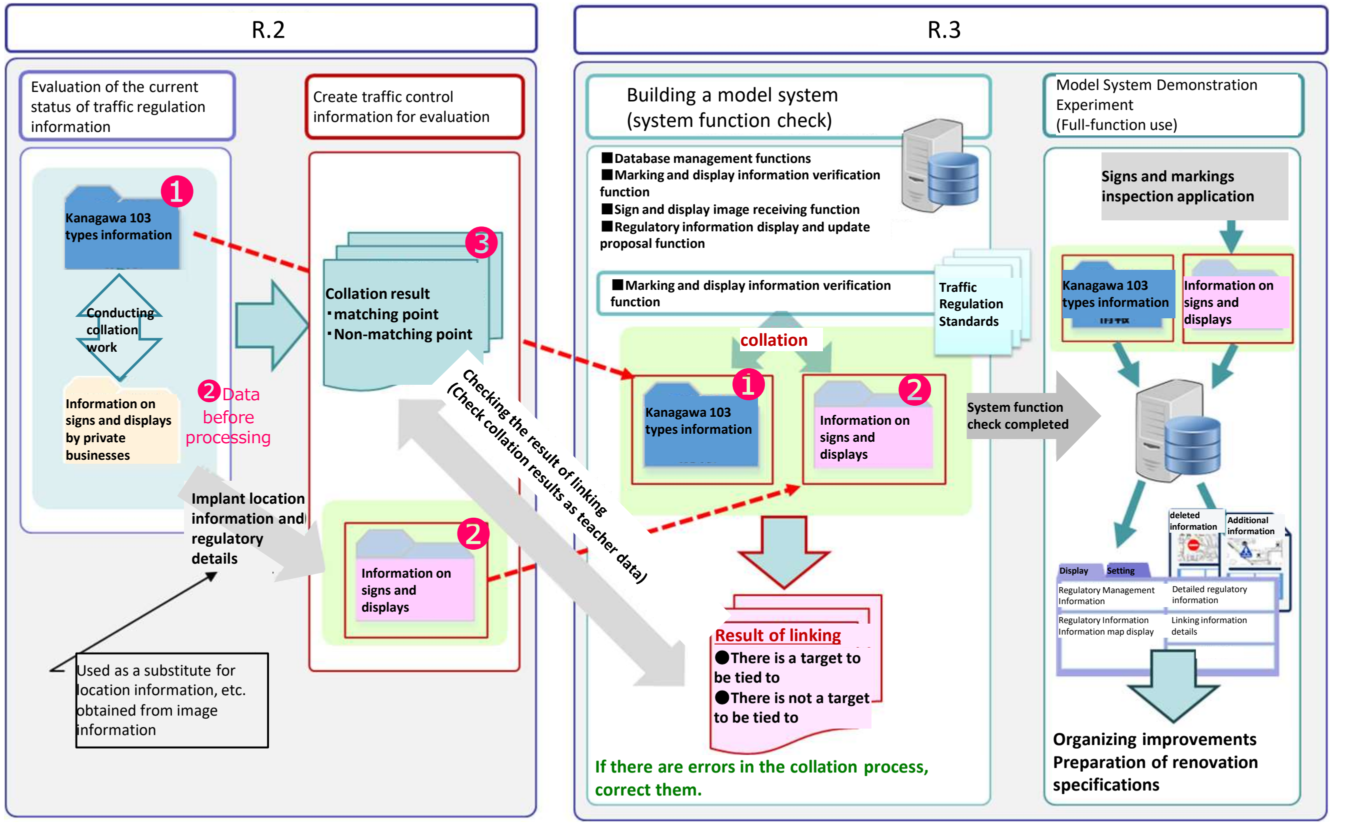


Fig.6. The role of traffic control information for evaluation

5. Preparation of draft specifications for the model system

iii)Preparation of draft specifications

Based on the results of the previous studies, the functional structure of the model system was examined.

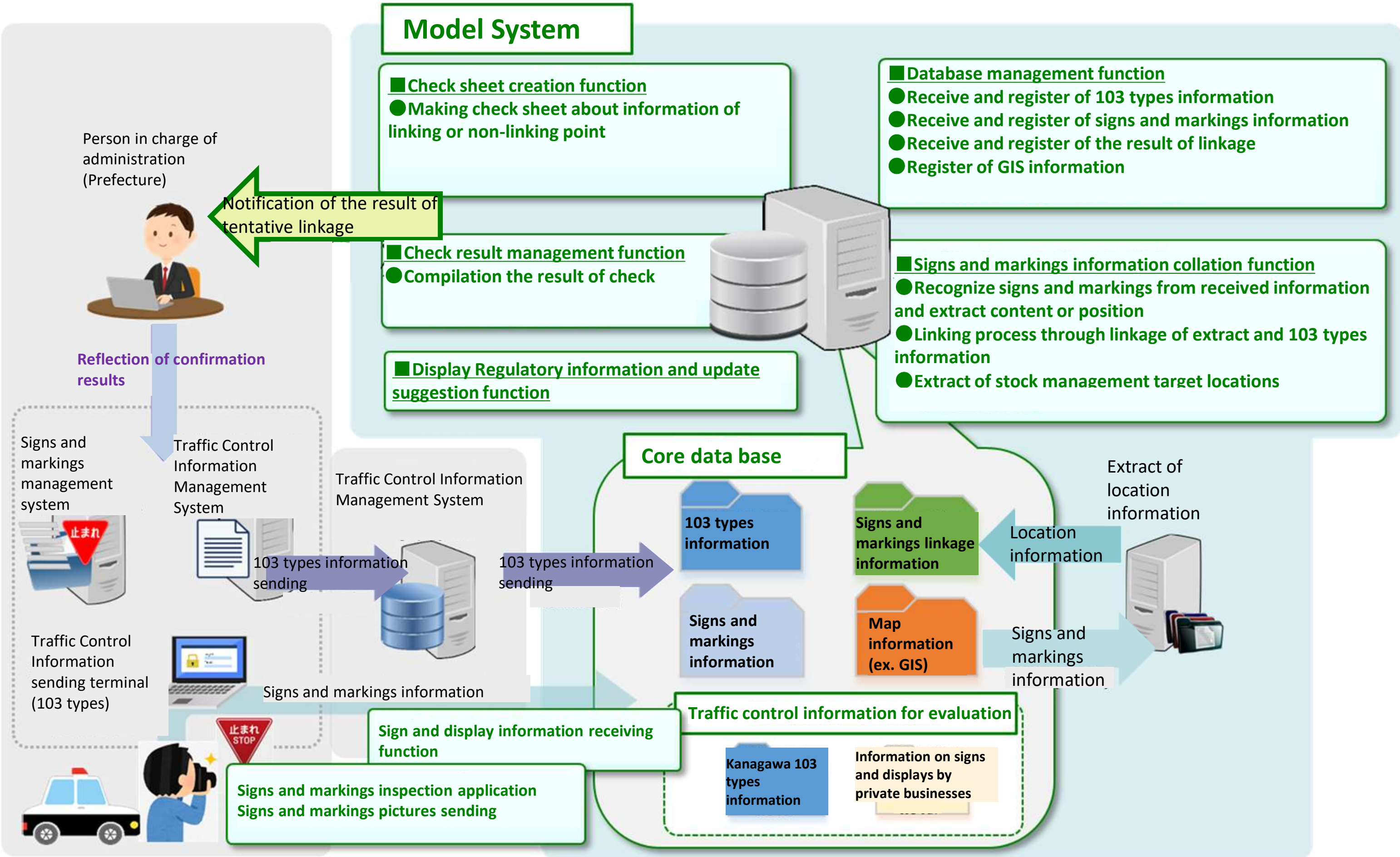
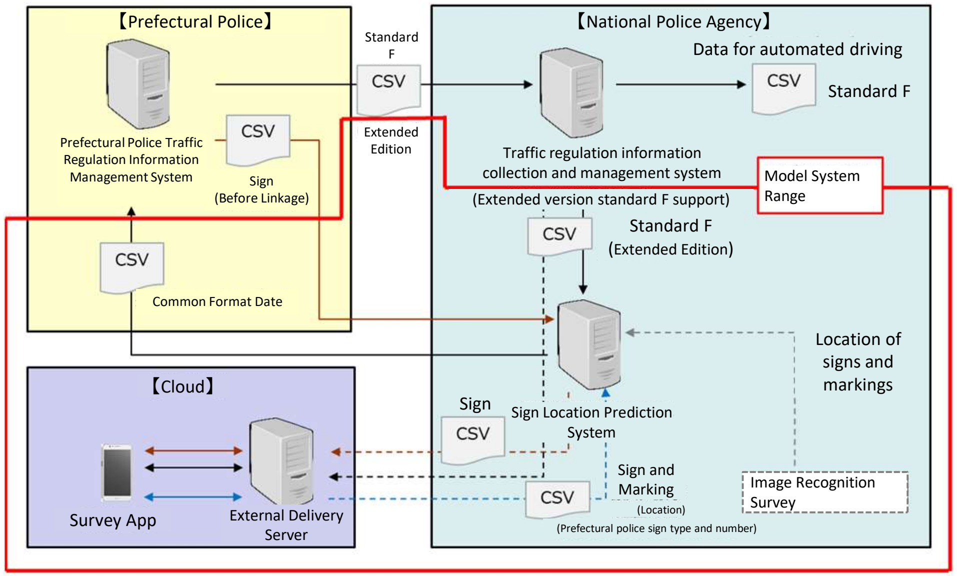


Fig.7. Image of the functional structure of the model system

5. Preparation of draft specifications for the model system

The equipment configuration of the model system was studied (Fig. 8), and the "Requirements Definition Document" and "Basic Design Document" were created as the specifications of the model system based on the functional configuration on the previous page.



(Abbreviation) Standard F : Traffic regulation information in standard format data(Meaning Decision)
Extended Edition Standard F : In addition to standard format data, data that links traffic regulation information (decision making) with signage information

Fig.8. Equipment configuration of the model system

Basic conditions for building and operating a model system efficiently and at low cost (draft)

- The basic functions of the model system are implemented in the main server
- Image analysis functions (e.g., location information extraction) shall use the services of an external server
- Sign and mark inspection functions (applications) are distributed or delivered as packaged software or downloadable applications.
- The main server is in the cloud (private)

【Definition of Elements】 Configuration Overview

1. Business Overview
2. Assumptions of Systemization
3. Outline of system functions
4. Interface
5. System non-functional requirements
6. System configuration
7. Equipment performance and installation layout and standards
8. Inspection standards
9. Installation plan
10. Maintenance and operation
11. Security
12. Demonstration experiment
13. Definition of terms

【Basic Design Document】 Configuration Overview

1. Equipment Overview
2. Function configuration and processing content performance
3. Interface configuration
4. Data structure
5. Inspection Standards
6. Reference Materials for Basic Design Documents

Screen Image

6. Holding a review meeting

For the development of the model system, the "Study Group for Improving the Data Accuracy of Traffic Regulation Information, etc." was established in cooperation with the public and private sectors. The results of the various studies were reported at the necessary timing, and a draft specification of the model system was prepared based on the opinions and suggestions raised by the committee members, etc., and was approved at the third study meeting. In addition, to prepare the draft specifications, the "New System Specification Study WG" was established to conduct technical studies, and two meetings were held.

Meeting	Date	Agenda
Part 1	Thu, Nov. 12th, 2020	1) Implementation policy 2) Schedule for the future
Part 2	Tue, Dec 22nd, 2020	1) Requirements for technology for automatic collection of traffic regulation information using image recognition technology 2) Technical requirements for matching and evaluation (interim report) 3) Results of the questionnaire survey 4) Schedule for the future
Part 3	Thu, Feb 18th, 2021	1) Confirmation of the wear condition of the markings 2) Results of verification evaluation in the model area 3) Model system functions and database structure (draft)

WG	Date	Agenda
Part 1	Tue, Jan 19th, Fri, Jan 22nd, 2021	1) Positioning of the model system 2) Questionnaire survey on existing traffic control information management systems 3) Database design of the model system
Part 2	Wed, Feb 10th, 2021	1) Results of a questionnaire survey on traffic regulation information management systems 2) Study of traffic regulation information DB 3) Outline of a simple registration function 4) Outline of the model system specifications (draft)

- The study group consists of the organizations listed in the table below.

Division	Organization	No. of people
Members	Knowledgeable (Tokyo Uni. : Project Prof.Ishinkawa, Assoc. Prof Kasakabe, Keio Uni. : Prof Kurihara)	3
	Ministries and agencies involved in automated driving	9
	Prefectural Police (Metropolitan Police Department・Kanagawa・Saitama・Chiba・Nagano・Gifu・Hyogo・Yamaguchi・Miyazaki)	19
	Concerned bodies	5
	Private sector providers of traffic control information management systems	5
Observers	Digital Map Maker	4
Total		45

- WG are conducted by any members

Participating Organizations	No. of Org.
National Police Agency	1
Prefectural Police	4
Private sector providers of traffic control information management systems	4

7. Future issues and response policies

The following table shows the issues that need to be resolved and the direction of action to be taken in order to build a model system, conduct demonstration experiments, and aim for full-scale operation in the next and subsequent years.

Table 6. Future issues and response policies

NO	Future issues	Details	Response policies
Issue 1	◆ Location Accuracy of Traffic Regulation Information and Priority Order for Improving Data Accuracy	The required positional accuracy differs depending on the use of traffic regulation information (based on the results of interviews with automobile manufacturers).	While taking into account the timing of deployment of automated driving by each company according to road classification, we will improve data accuracy while prioritizing.
Issue 2	◆ Response to opinions and proposals at review meetings, etc.	(1) Handling of traffic regulation information that changes with time of day and day of week	It is necessary to study the traffic regulations that change depending on the time of day and day of the week, such as the change in the median line.
		(2) Cooperation with DB managed by parties other than the police	We will consider a method to provide information in an integrated manner by collaborating with the DB held by road administrators.
Issue 3	◆ Need to review the standard format (103 types)	(1) Lack of day-of-week code definition (2) Insufficient definition of the direction of regulation (3) Insufficient definition when there are multiple entry directions for one regulation (4) Insufficient input definitions for data items that do not apply (5) Discrepancy between data format attribute definition and description (6) Insufficient definition of the storage order of coordinates	Clarification and review of the standard format will be considered, as the existence of data that is not specified in the standard format may be a factor that prevents the full functioning of information provision to automated vehicles and the automation of matching in the future.
		(7) Add decision number, etc.	In order to utilize the data in the traffic regulation information management system of the prefectural police, consider adding the decision-making number and management number of the prefectural public safety commission to the standard format.
Issue 4	◆ About traffic regulation information that has not been converted to data	The challenge is to convert information called "drawing regulations", in which a large number of decision-making information is handwritten on paper-based maps, into data.	A model system will be developed in the next fiscal year to reduce the workload of prefectural police.

8. Summary

In this study, information on signs and markings is captured by smartphones and in-vehicle cameras, etc., and automatically collected with uniform data accuracy on the type of regulation, location information, and aging of facilities, etc., using image recognition technology, and checked against traffic regulation information managed by the police. In addition, we conducted a study on the development of a system for efficiently improving the data accuracy of traffic regulation information and stock management through a simple registration function. The method of automatically collecting information on signs and markings using image recognition technology from the images of drive recorders, etc., which was studied this fiscal year, can improve the range and freshness of information, but requires repeated driving for accurate data collection, which poses a cost issue. Therefore, we studied the configuration of a model system that mainly collects information on local signs and markings by using a smartphone application during construction and inspection of signs and markings by on-site police officers and construction workers. A questionnaire survey of the prefectural police revealed that a great deal of labor is required to link the decision-making information of traffic regulations by the public safety committee with signs and markings, and the model system is designed to support this work.

In addition, during the process of the study, it was confirmed that the standard format currently used to indicate the 103 types of traffic regulation information has a range of interpretation due to some undefined items. This is an issue that needs to be resolved in the future when handling traffic control information mechanically, including model systems.

Based on the results of these studies, the direction of the specifications for the model system was determined, and the results were discussed at the third study meeting and approved by the committee members. In the next fiscal year, a model system based on these specifications will be constructed and a demonstration experiment will be conducted. The chairperson of the study group commented that we should find the balance point between "total optimization" and "partial optimization" in constructing the model system. Excessive overall optimization will impair partial optimization. The current traffic regulation information management systems of prefectural police forces are highly unique, and it is difficult to make a system that takes all the characteristics into account, but it is desirable to optimize the system while solving the problems.